ARPA-E: Emerging Ideas II
- Renewable Energy Forecasting
- Real Time Electricity Pricing
- Low- or No-Water Power Plant Cooling
- Higher Efficiency Solar

10:30am – 11:30am

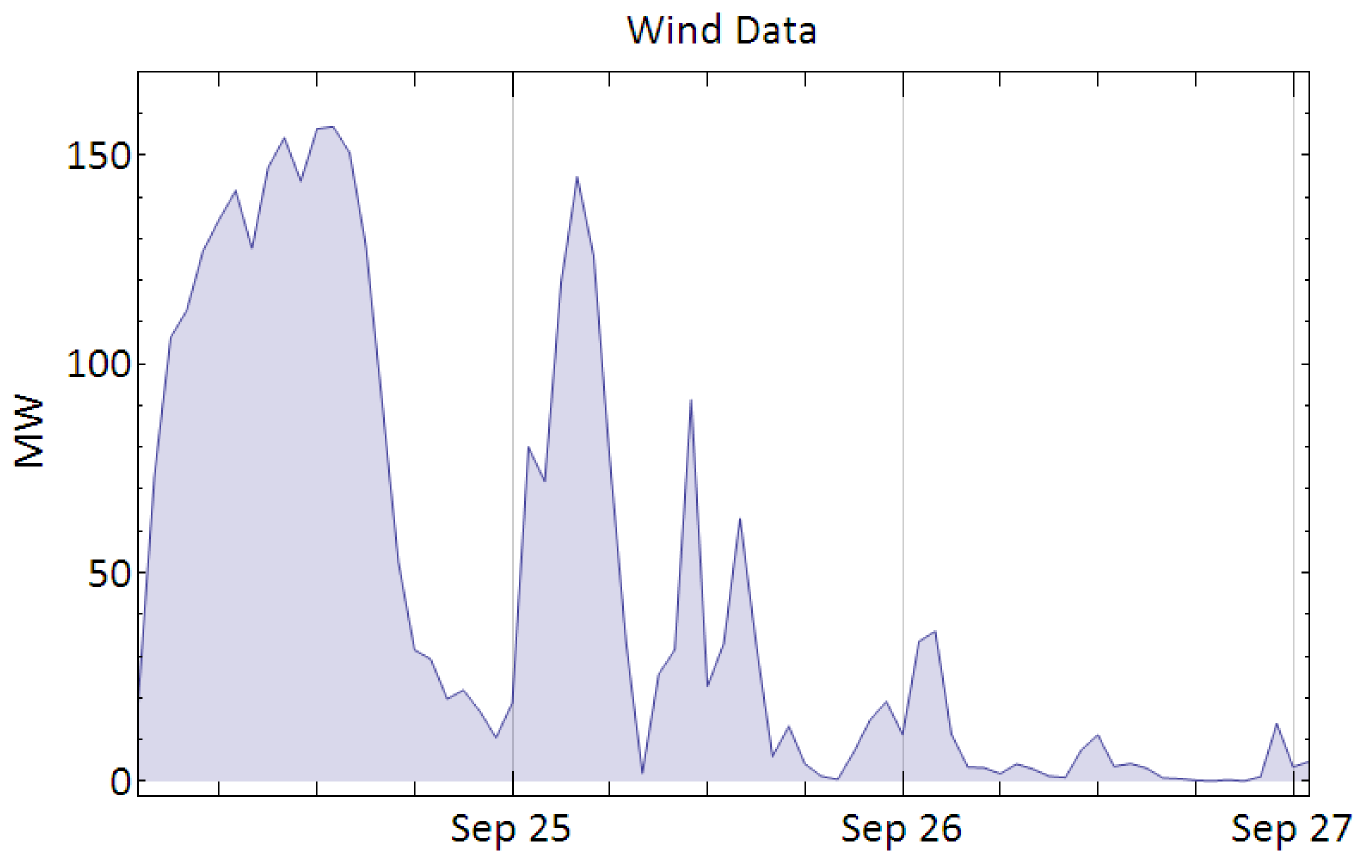
Renewable Energy Forecasting

Phil Larochelle

ORISE Postdoctoral Researcher

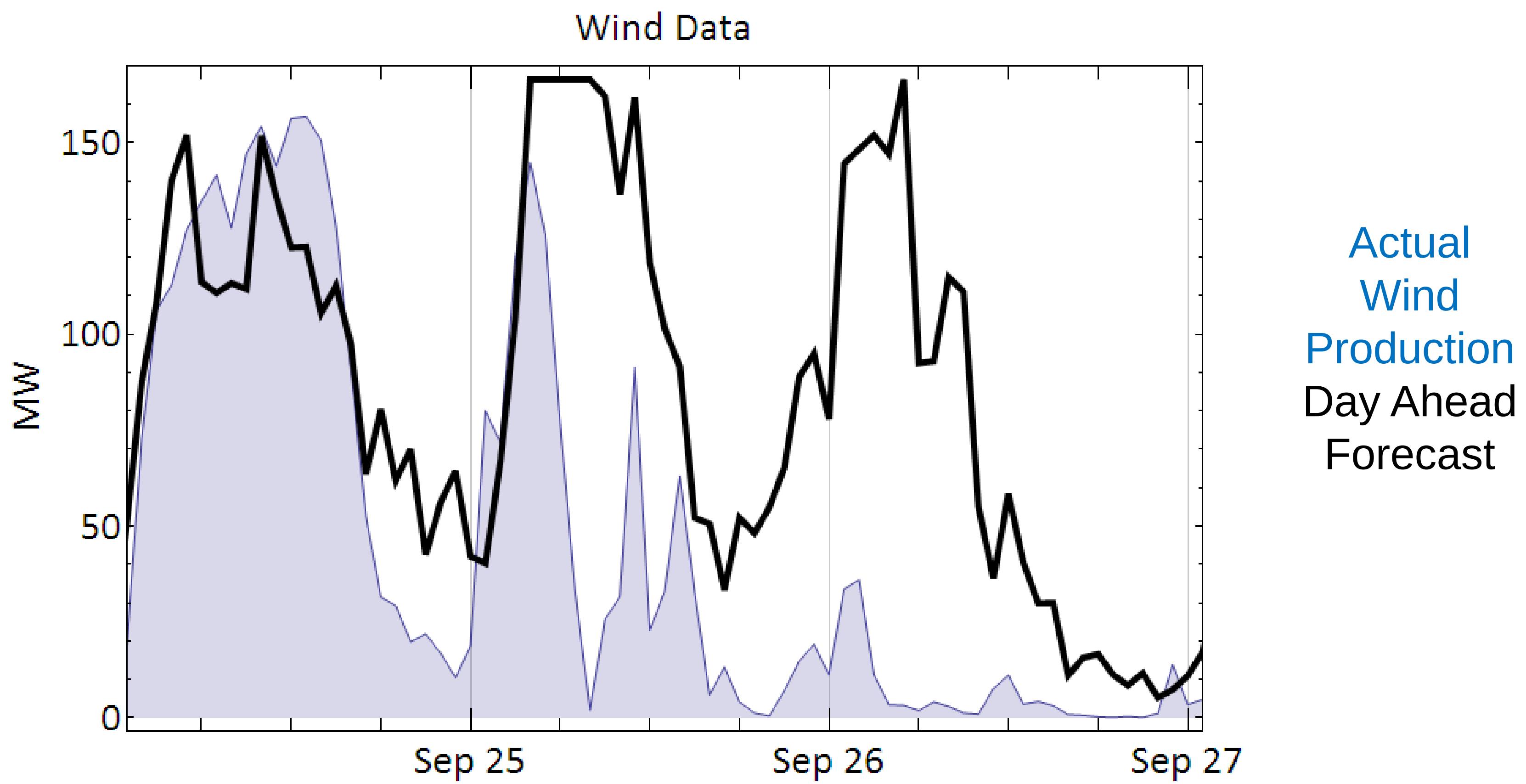
Contractor to ARPA-E

Wind is Variable

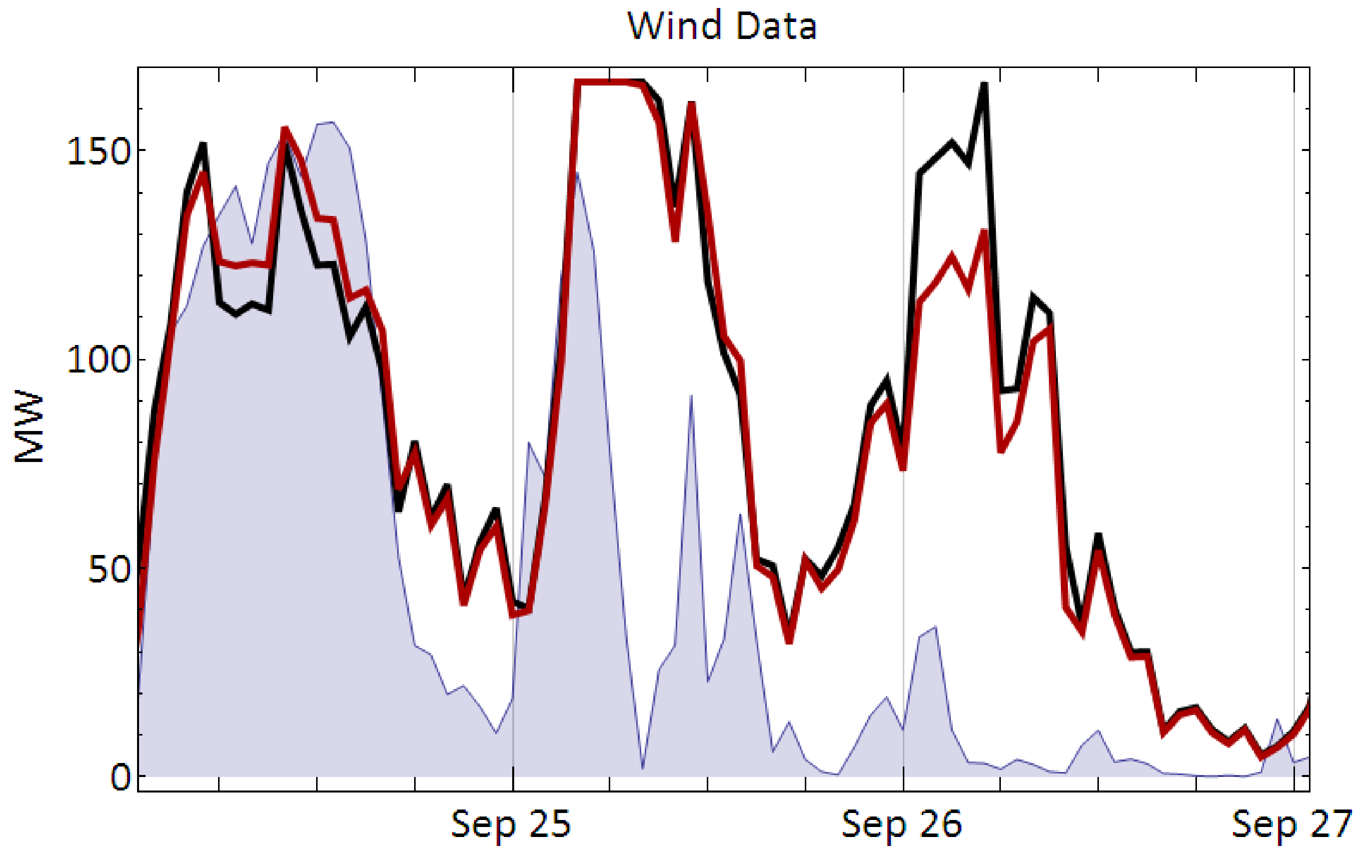


Actual Wind Production

Wind is Variable & Forecasts are Imperfect



Wind is Variable & Forecasts are Imperfect



Actual Wind Production
Day Ahead Forecast
4 Hour Ahead Forecast

State of the Art Forecasting Technology Performance

Table 2

Average Wind Forecast Error by Time Frame

	Forecast Error	
	Single Plant	**Region**
Hour Ahead		
Energy (% Actual)	10 – 15%	6 – 11%
Capacity (% Rated)	4 – 6%	3 – 6%
Day Ahead		
Hourly Energy (% Actual)	25 – 30%	15 – 18%
Hourly Capacity (% Rated)	10 – 12%	6 – 8%

Source: Smith, 2009.

Bad Forecasting Results In:

- Requirement of additional balancing reserves
- Underproduction/ curtailment of wind and solar
- Contingencies and outages

The Value of Wind Power Forecasting

Preprint

Debra Lew and Michael Milligan
National Renewable Energy Laboratory

Gary Jordan and Richard Piwko
GE Energy

	10% Forecasting Improvement	20% Forecasting Improvement
14 % Wind Penetration	$140 M	$260 M
24% Wind Penetration	$500 M	$975 M

Techno-Economic Goal

Measurement and Data Analytics that Result in > 40% Improvement on State of the Art Forecasting Techniques for Wind and Solar Power

Technologies that Can Do It

Hardware: **Improved Sensors (Accurate, Low-Cost and Remote)**

Software: **Data Aggregation, Analysis and Forecasting**

Existing Wind Sensing Techniques

Anemometer

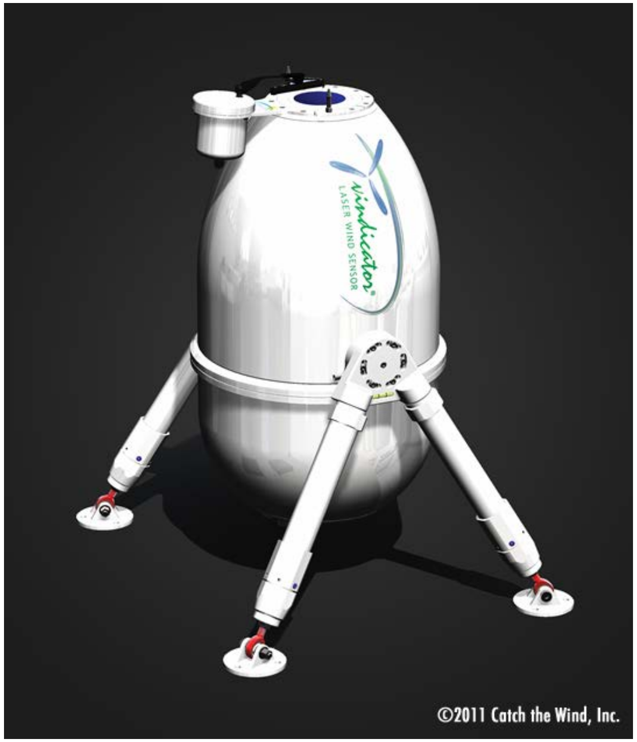
RADAR

SODAR

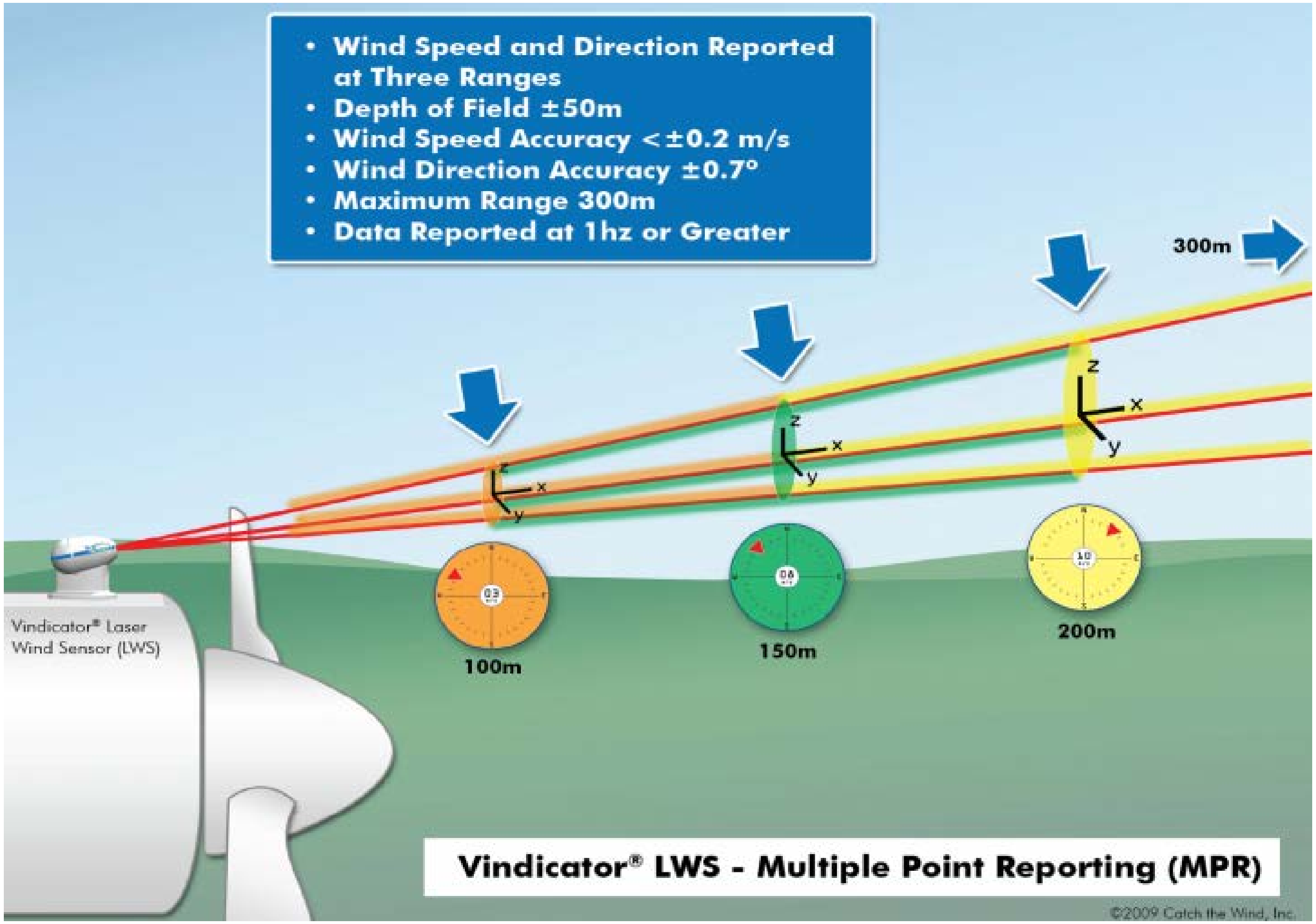
(Sound Detection and Ranging)

LIDAR: Light Detection and Ranging
Look at the Doppler Shift of Back Scattered Light

State of the Art: Stationary Installations for the Characterization of Resources



Ranged LIDAR: Can we push this technology and make it ubiquitous? Can we extend the range > 1 km?



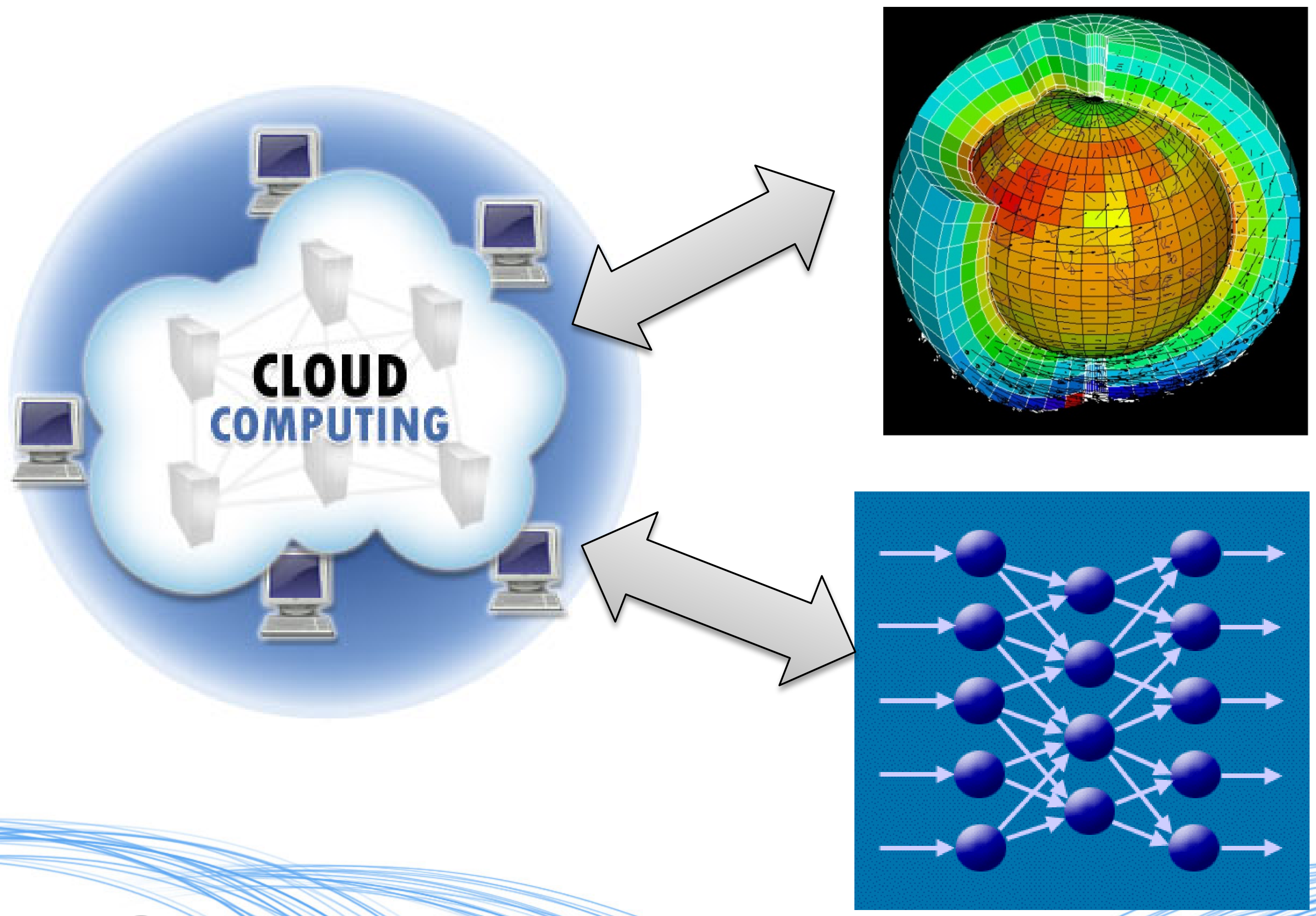
Solar Sensing Techniques: How do you deploy widely and process the data?

Total Sky Imagers

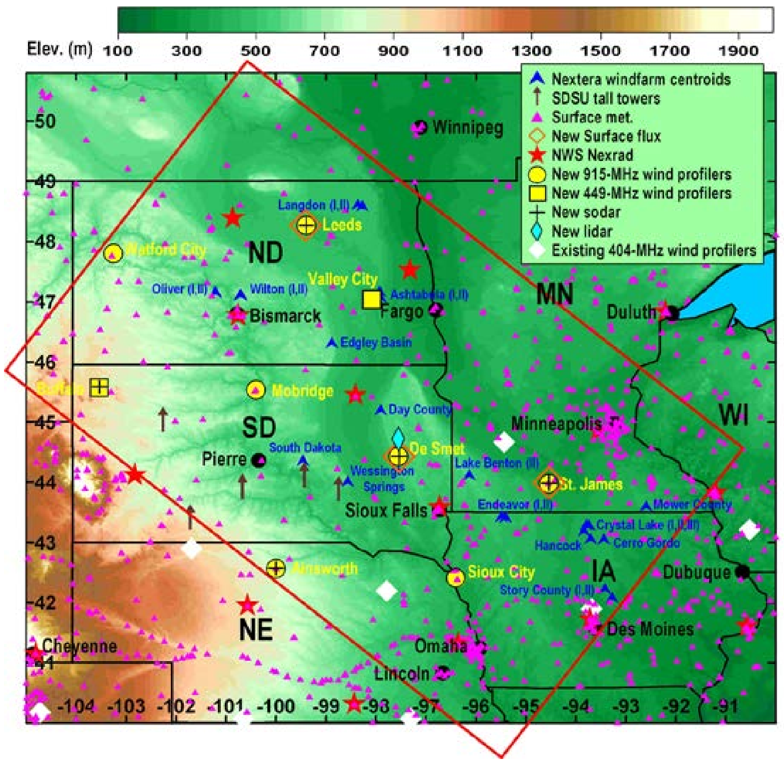
PV Cell = fast time scale irradiance sensors

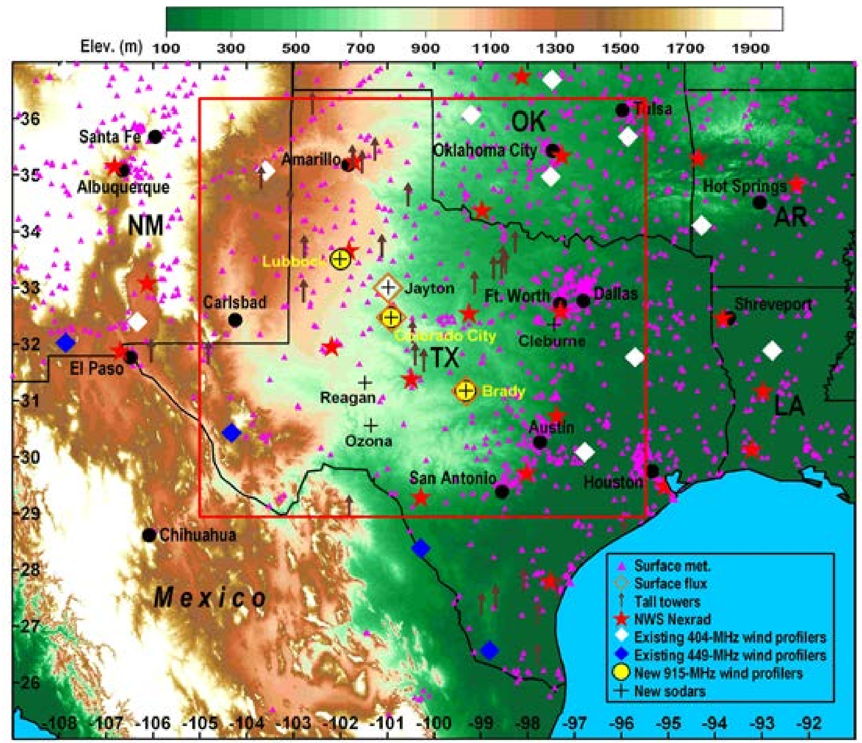
How do you log and communicate the data?

Software: Can we bring Cloud Computing Resources to Numerical Weather Prediction Models and Machine Learning?



How Can we Complement Existing DOE Projects such as the DOE/NOAA Wind Forecasting Improvement Project





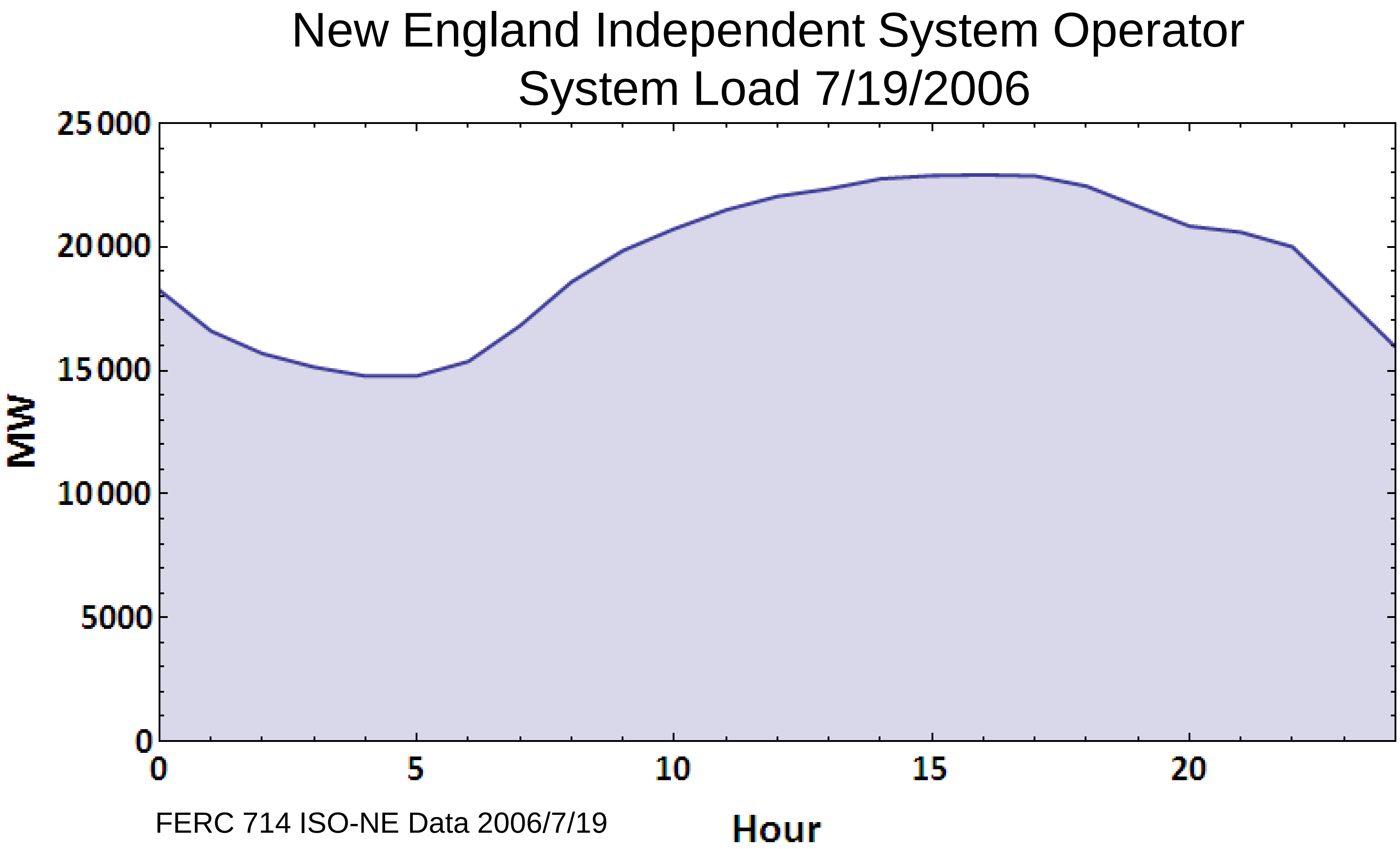
Forecasting Program Name:

P REDICTING
R ENEWABLE
O PTIMUM
P RODUCTION OF
H EAT &
E LECTRICITY
T ECHNOLOGIES

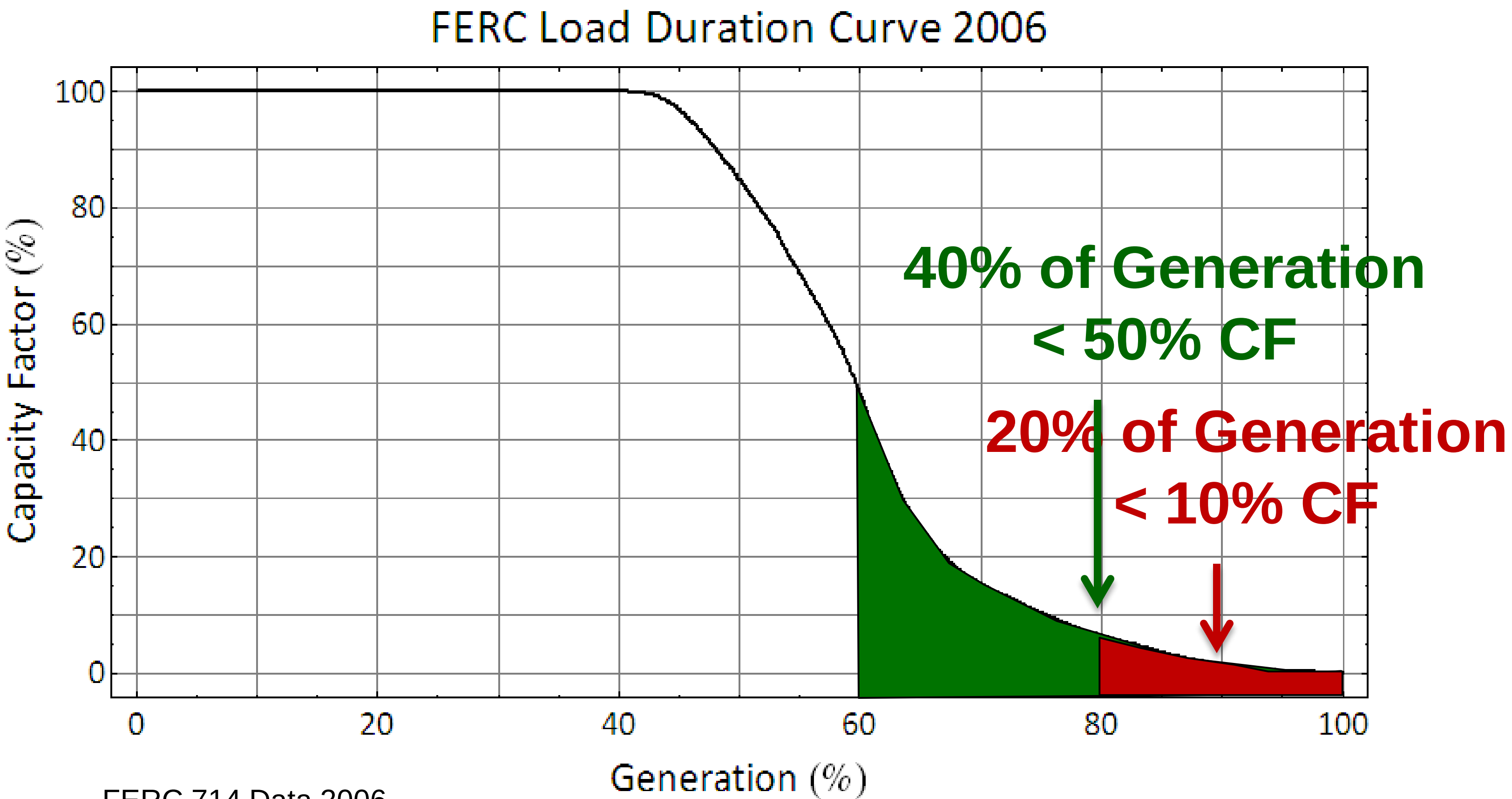
Real Time Electricity Pricing

Timothy Heidel
ARPA-E Fellow

Demand for electricity varies

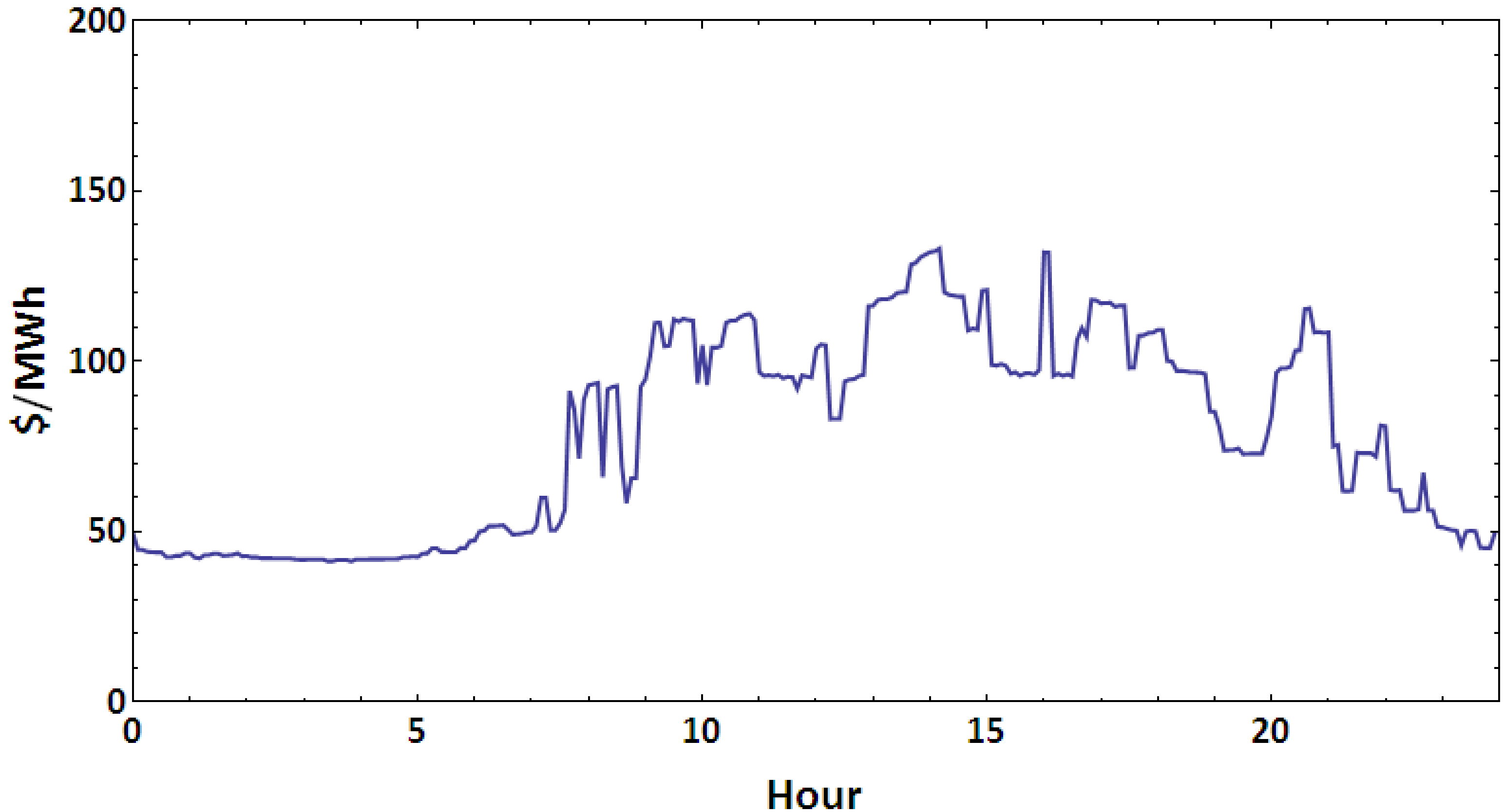


Varying demand yields low capacity utilization



FERC 714 Data 2006

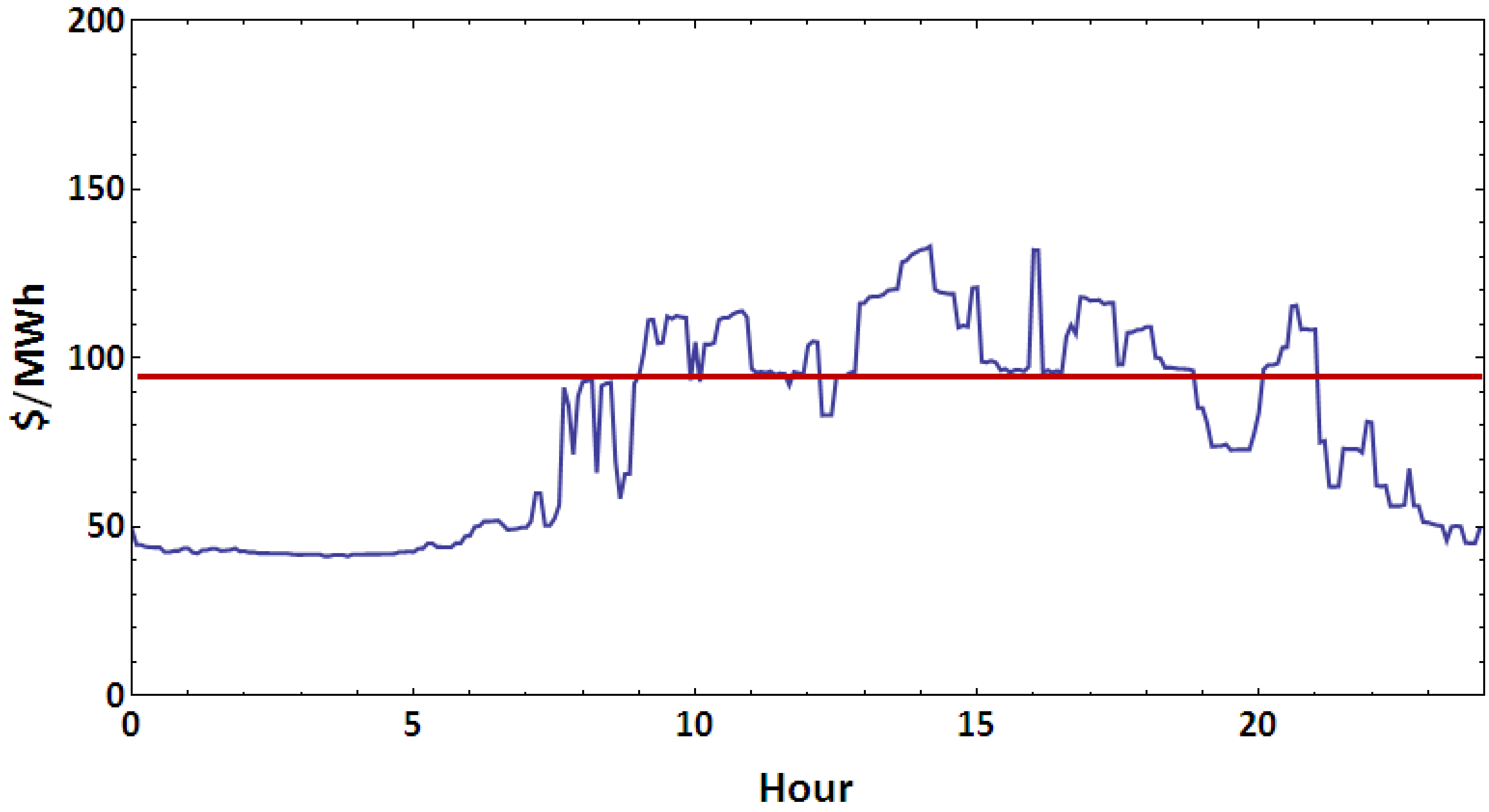
The cost of generation varies



ISO-NE Data 2011/7/19

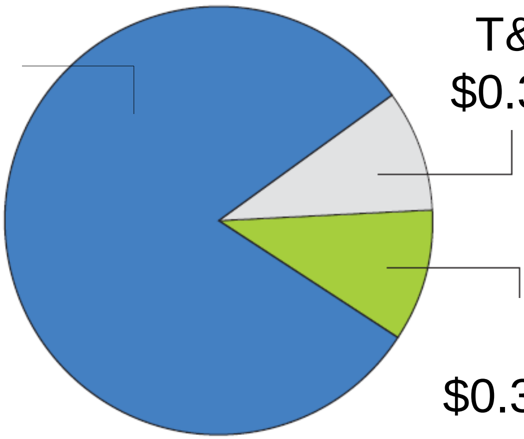
The cost of generation varies

BUT, the price consumers pay is constant



ISO-NE Data 2011/7/19, PEPCO Residential Rate 2012

Dynamic pricing could avoid the need for new capacity and reduce costs.



Annual Long-Run Savings:
~ $ 3 Billion

Annual Short-Run Savings:
~ $5-10 Billion

A. Faruqui, R. Hledik, S. Newell, J. Pfeifenberger, "The Power of Five Percent," The Brattle Group, May 2007.

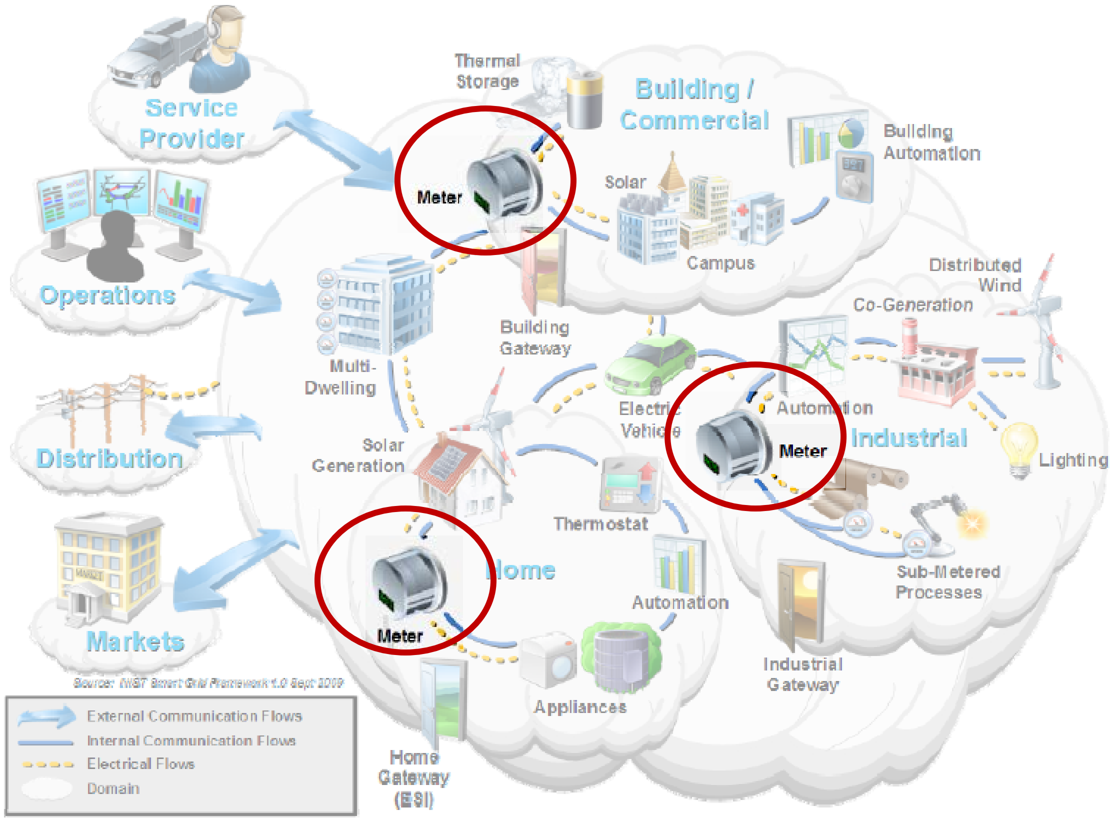
Dynamic pricing requires more granular measurements of electricity consumption.

- Smart meters are too expensive today: $150-$300 per meter

Substantial cost reductions are needed

Existing approaches rely on a meter at every customer location

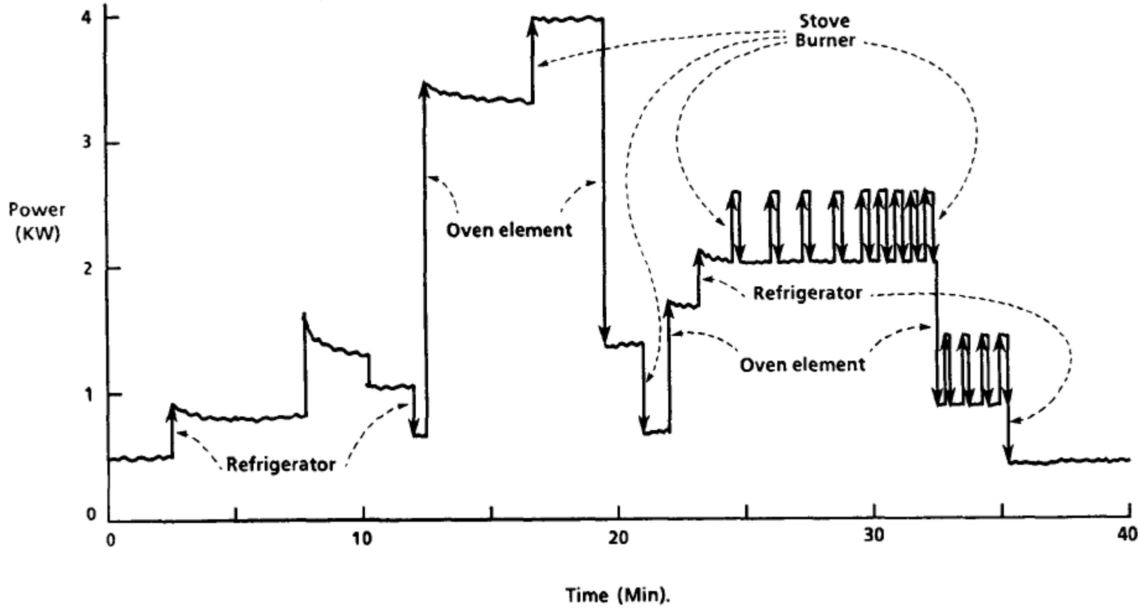
Smart Grid Customer Domain



NIST Framework and Roadmap for Smart Grid Interoperability Standards, Release 1.0 (2010)

Approaches that do not require new meters?

- Individual appliances measure power consumption
  - Need cheap, secure, accurate integrated power measurement.
- Substation Measurement
  - Nonintrusive load monitoring on distribution feeders



Hart, “Nonintrusive Appliance Load Monitoring,” IEEE (1992)

Potential Program Name:

P ROVIDING

R EAL TIME

I NTELLIGENT

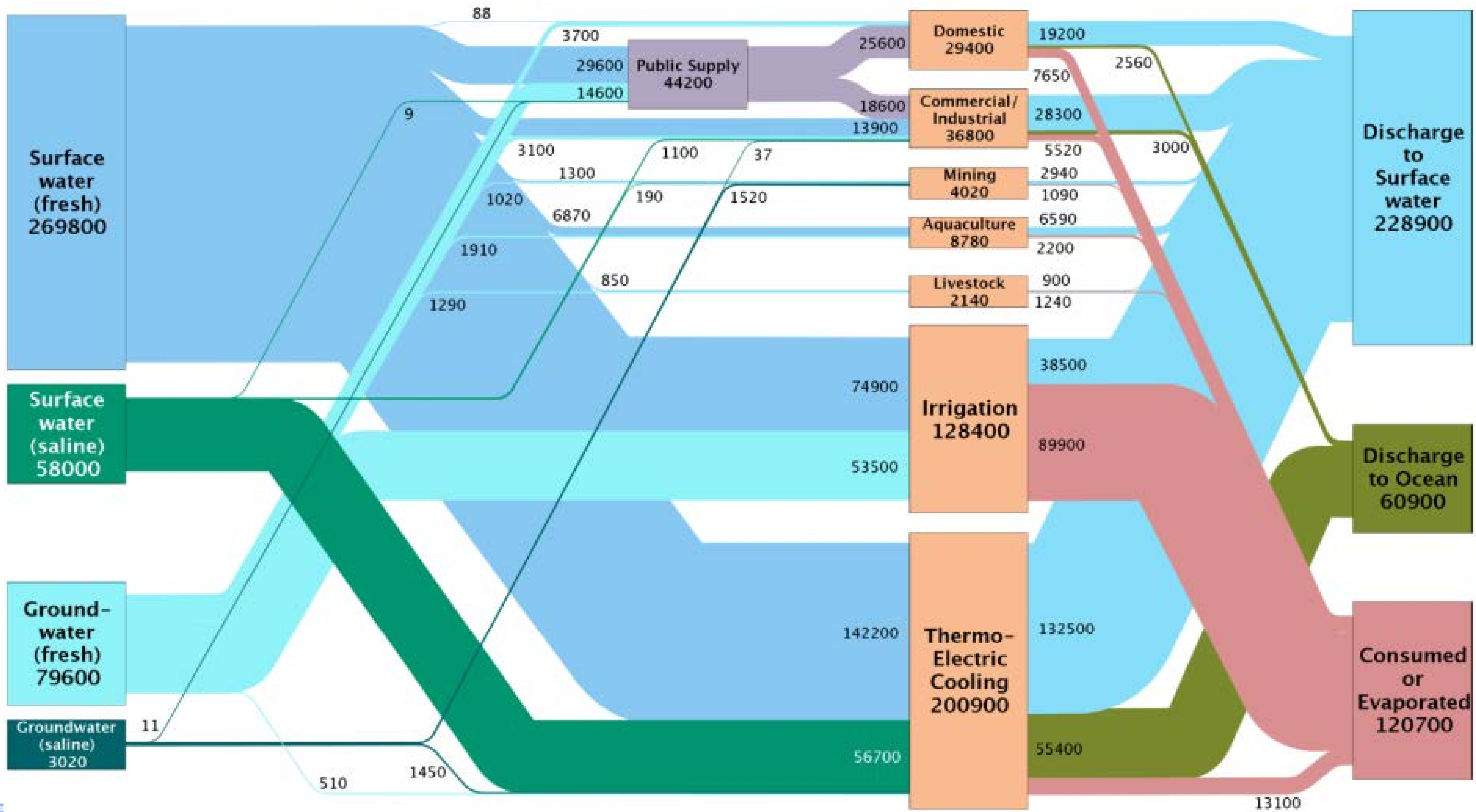
C OSTS FOR

E LECTRICITY

Low- or No-Water Power Plant Cooling

Nicholas Cizek
ARPA-E Fellow

Estimated US Water Flows 2005 (MGD), Total: 400 BGD



AJ Simons (LLNL and USDOE), 2010. Based on J Kenny (USGS), 2009

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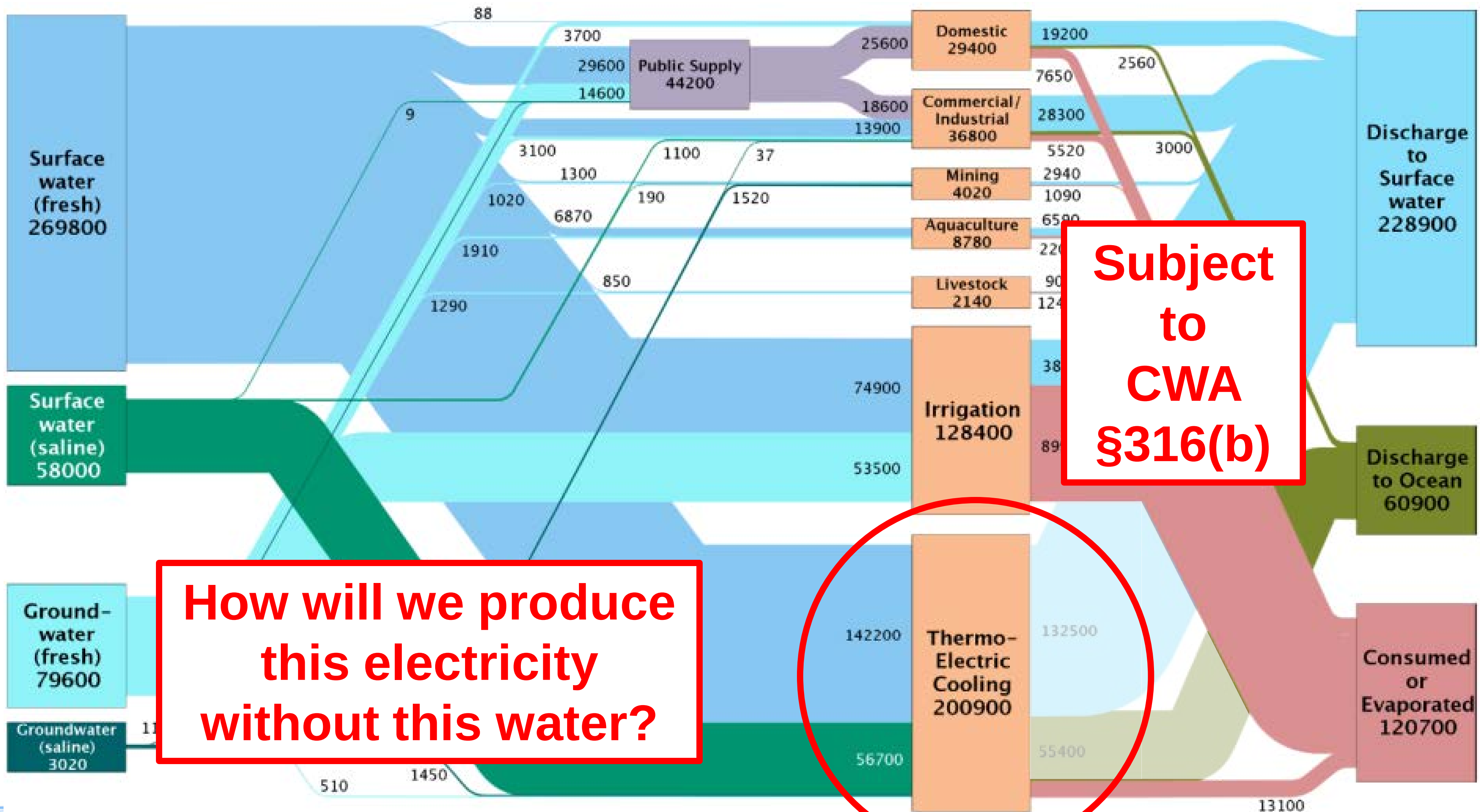
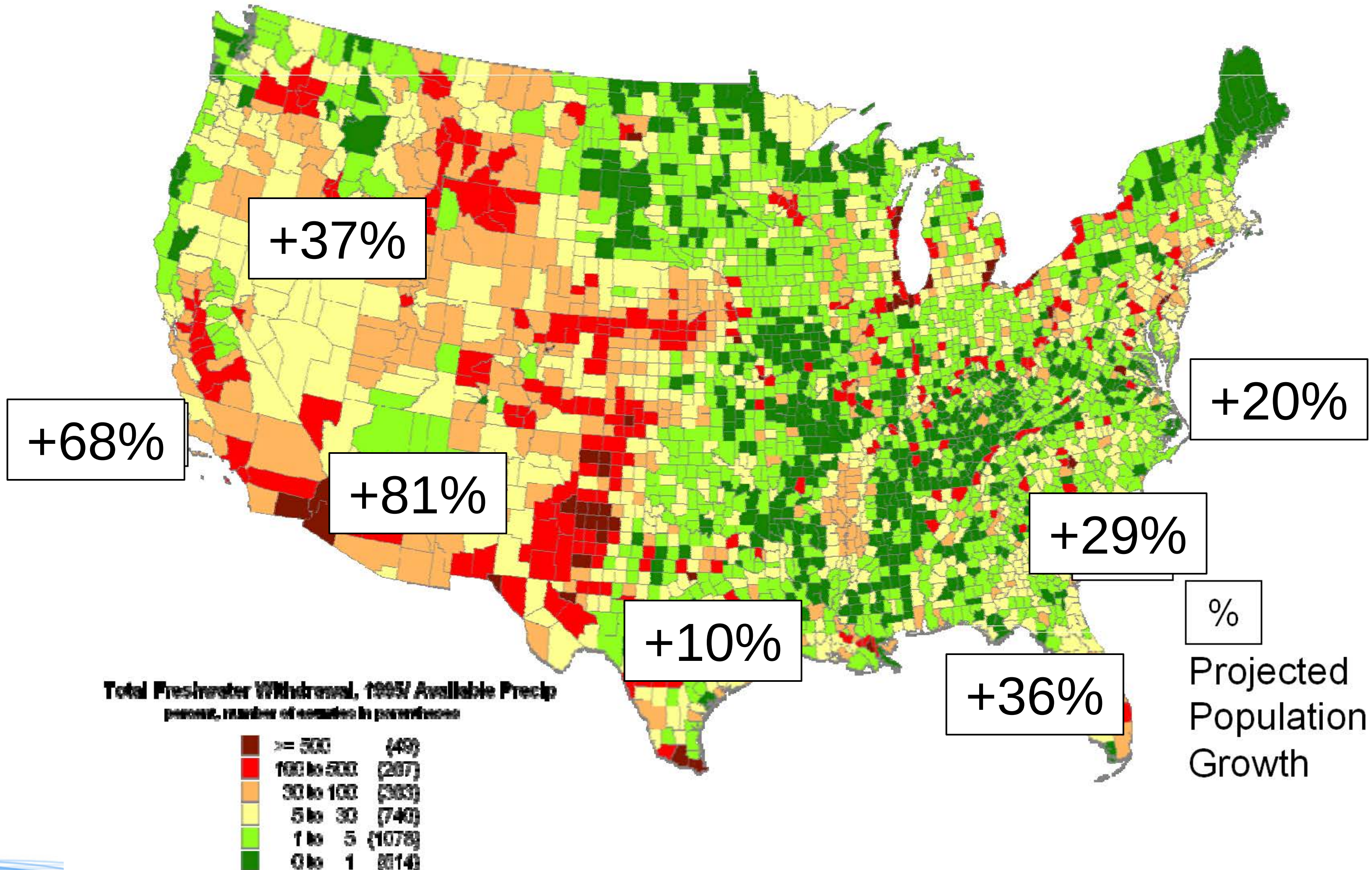


AJ Simons (LLNL and USDOE), 2010. Based on J Kenny (USGS), 2009

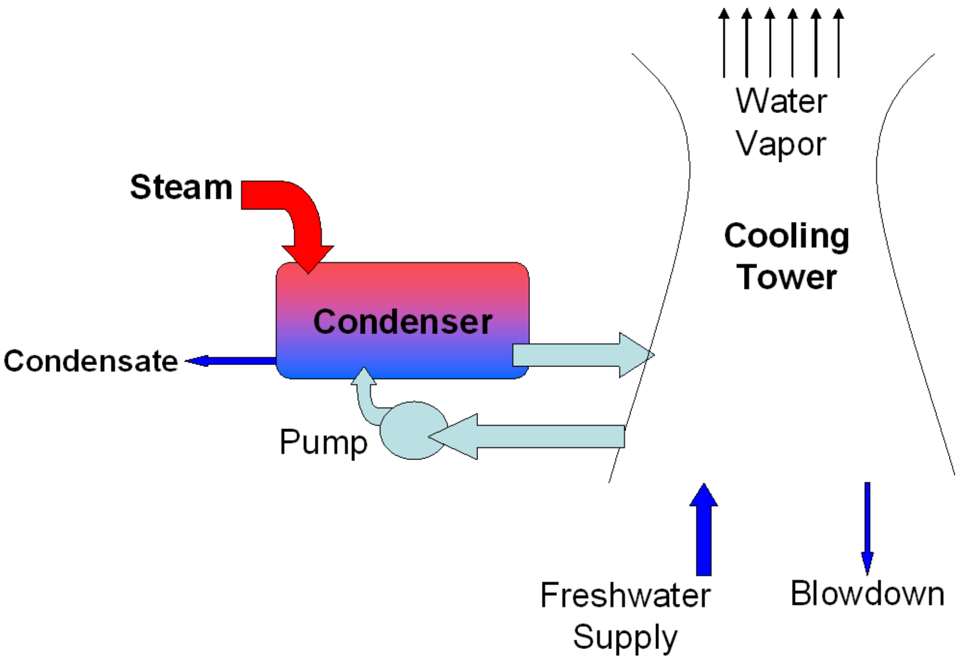
30% Population Increase by 2030, Mostly in DRY PLACES



Solley (USGS), 1998; EPRI, 2003; Campbell (US DOC), 1997

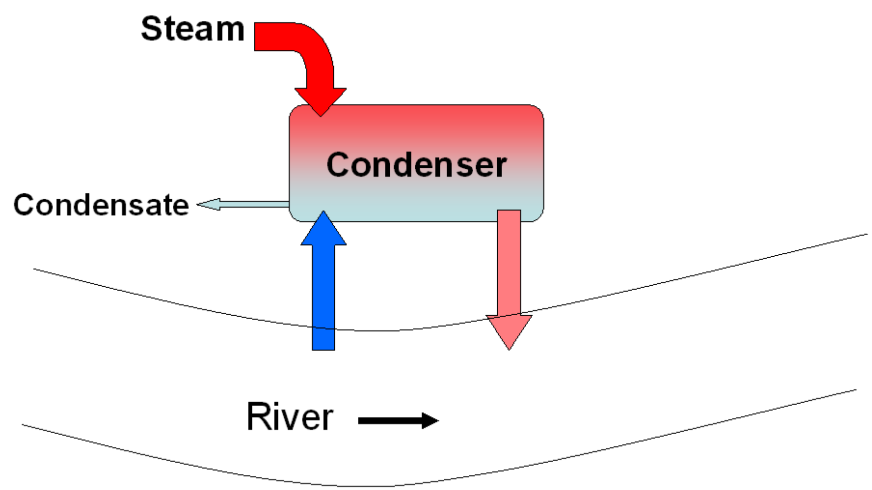
Traditional Power Plant Cooling

“Closed Loop” Cooling



Q Evaporates H_2O

“Open Loop” Cooling



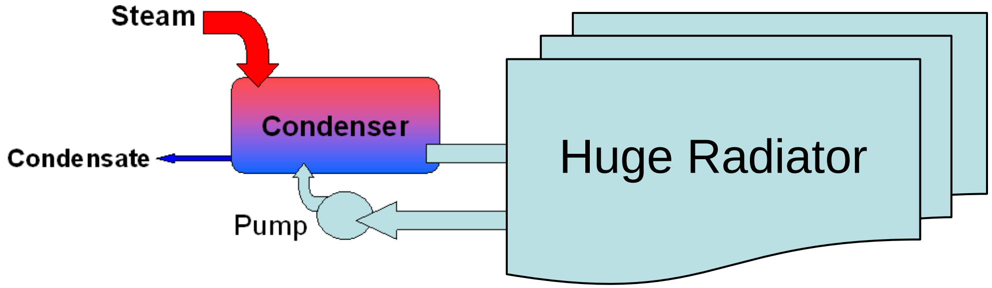
Q Raises River Temp

- Raises Air Temp
- Evaporates H_2O

Problem Statement

Dissipate GW-scale low-grade heat (95 F) into air without evaporating water

Air Cooled Power Plant



Q Raises Air Temp Only

But $T_c = T_{air,day}$ instead of $T_{water} = T_{air,ave}$

~10% Less Electricity

Are there dry-cooling tech pathways to achieve

$T_c = T_{air,ave}$, not $T_c = T_{air,day}$

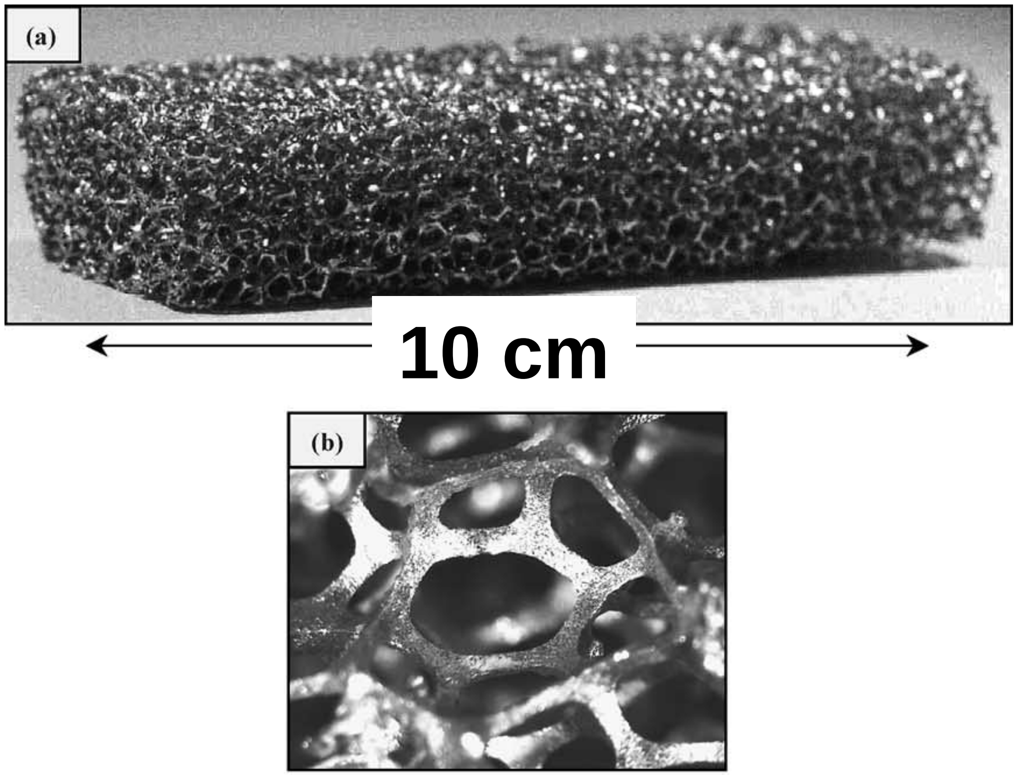
to avoid ~10% efficiency loss?

Thermal Battery (low vapor pressure)

- Earth
- Liquid besides water

Dry Cooling Tech Paths To Wet Cooling LCOE

Increase Surface Area – thermally conducting polymer, metal foam

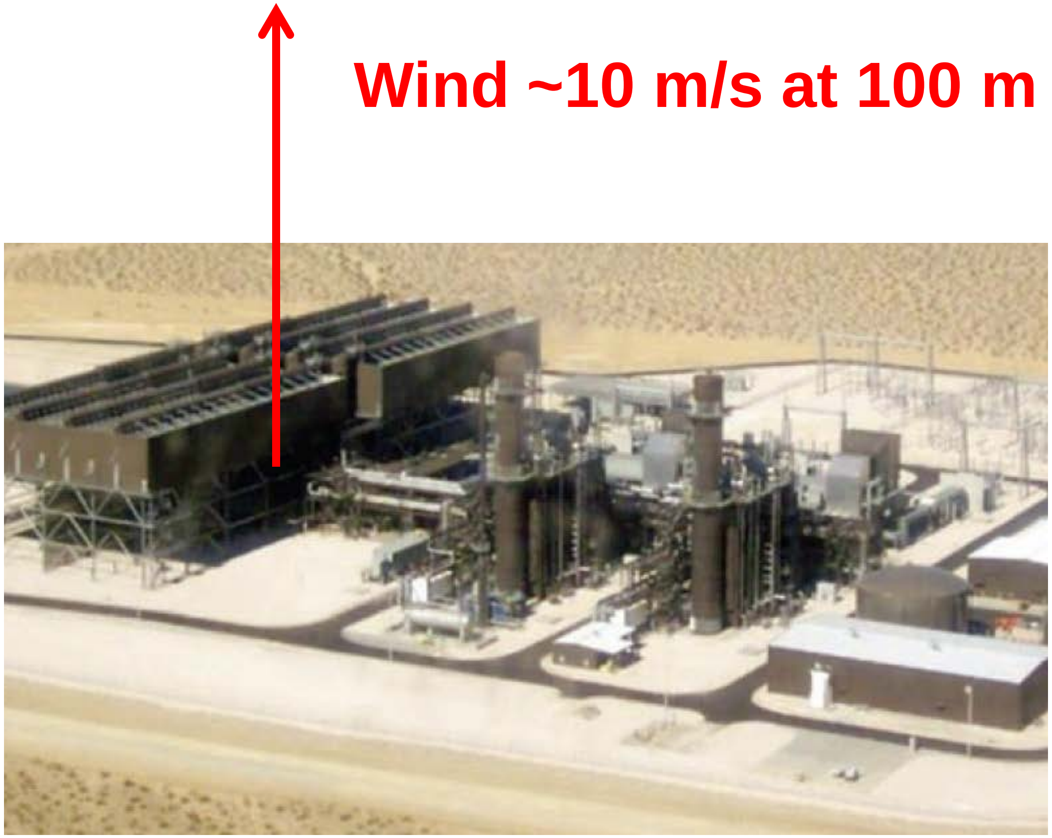


7 mm

Boomsma, *et al*, Mechanics of Materials, 2003

Dry Cooling Tech Paths To Wet Cooling LCOE

Increase Air Speed – elevate condenser



Dry Cooling Tech Paths To Wet Cooling LCOE

Increase Heat Transfer Coefficient – coatings, nanostructures

Non-Rankine bottoming cycle – parallel Stirling

Techno-Economic Goal

Dry Cooled Power Plant LCOE

< 5¢/kWh

Low-/No-Water Power Plant Cooling Name

I MPROVING

C OOLING

E FFICIENCY of

PO WER

P LANTS

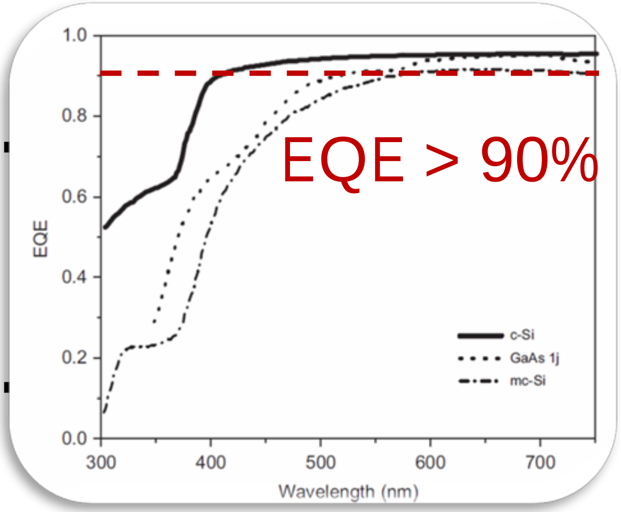
Higher Efficiency Solar

Asegun Henry
ARPA-E Fellow

Collection

Conversion

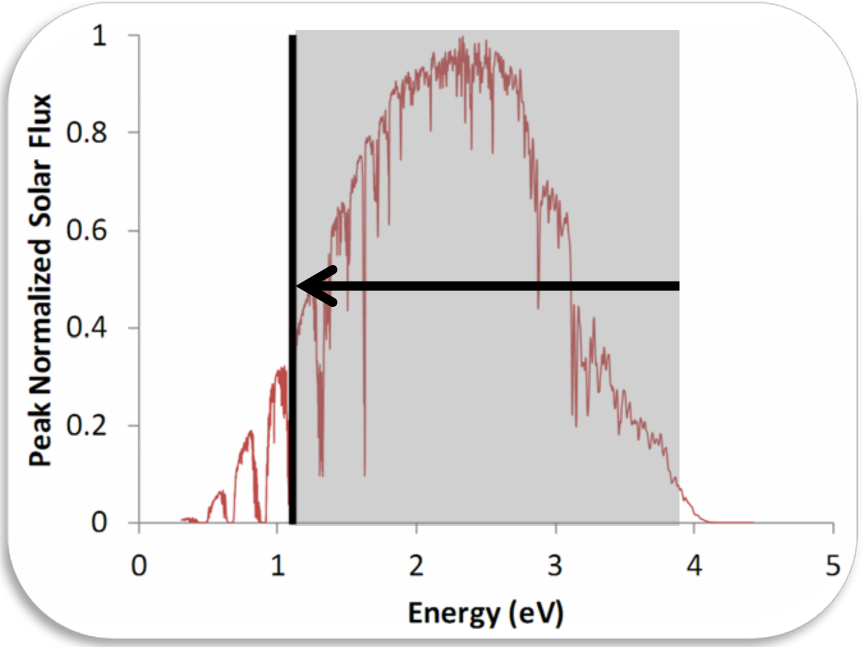
?



Cheap

Efficient

Collection



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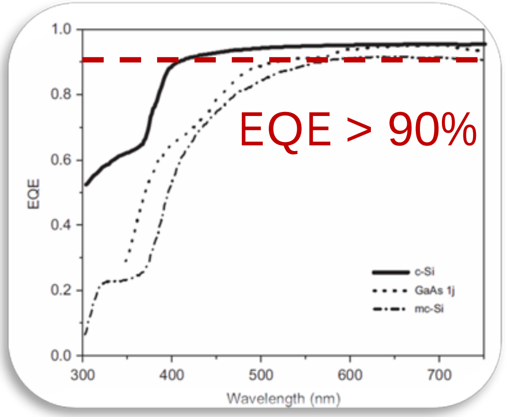

Sacrifice Efficiency

Collection

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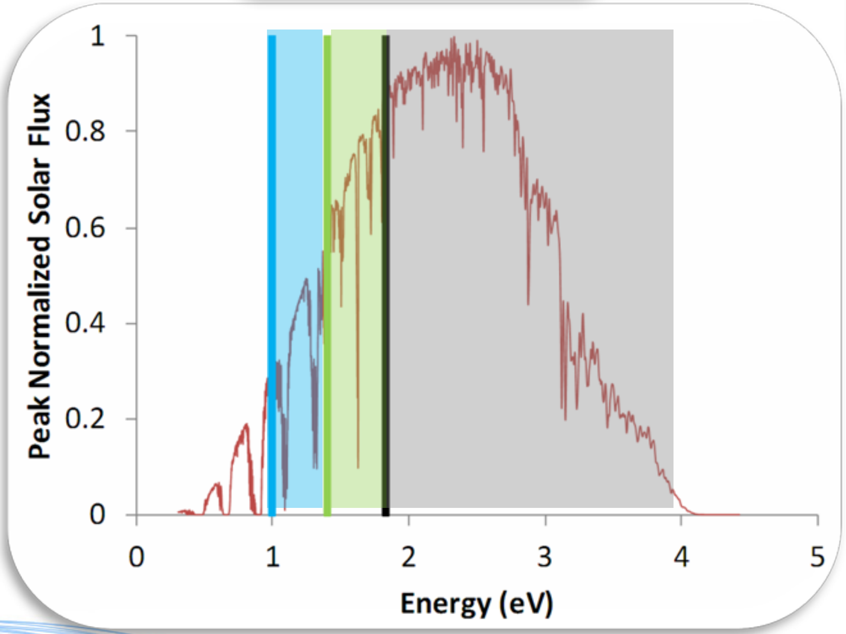

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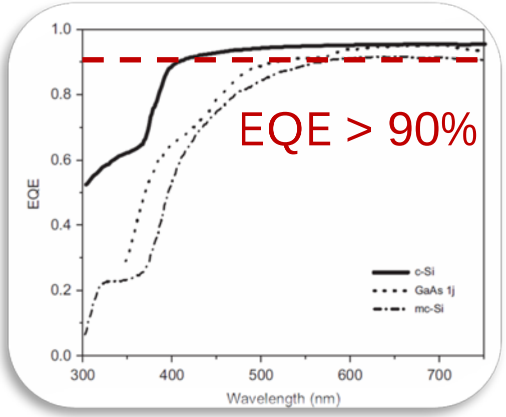

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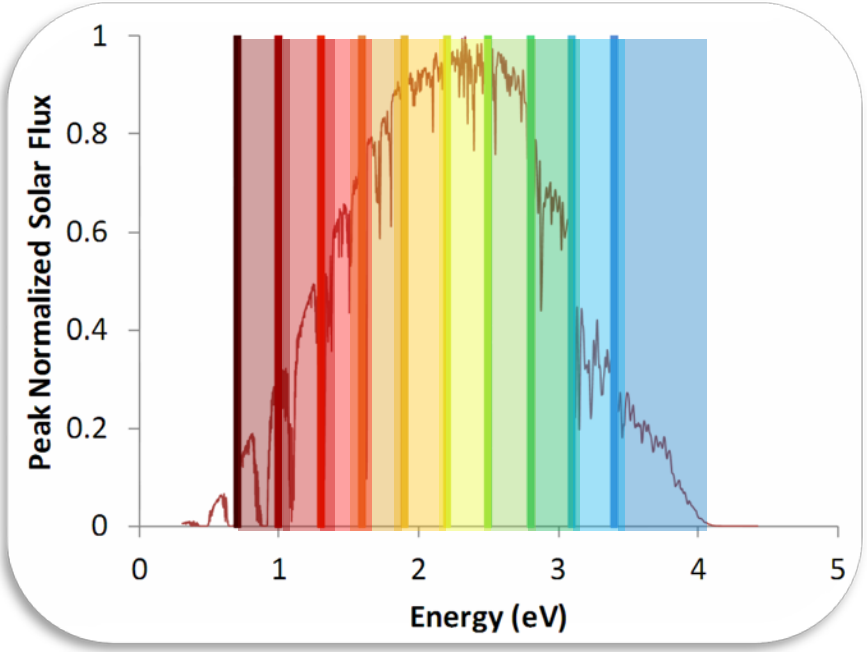

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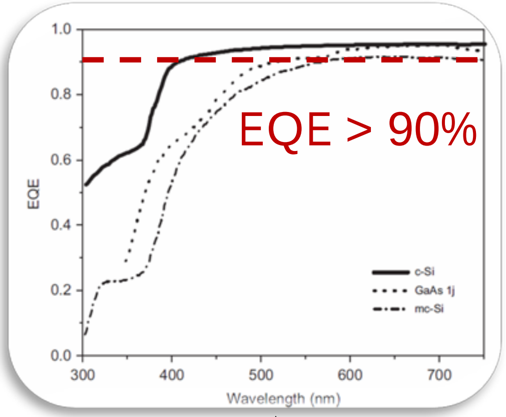
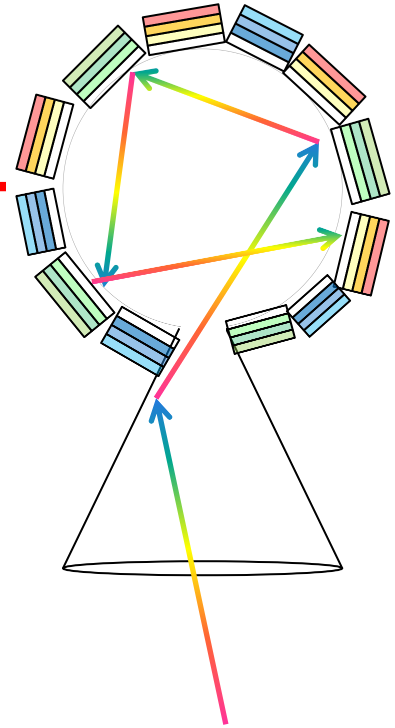


Optical System
Improves Efficiency

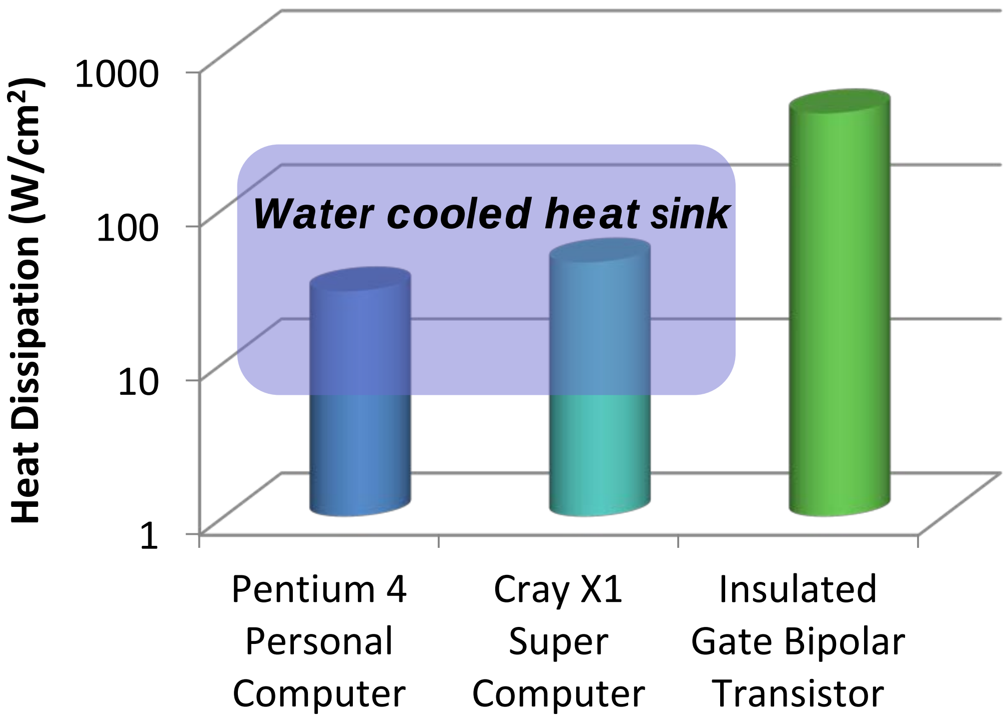
What about power tower CPV?

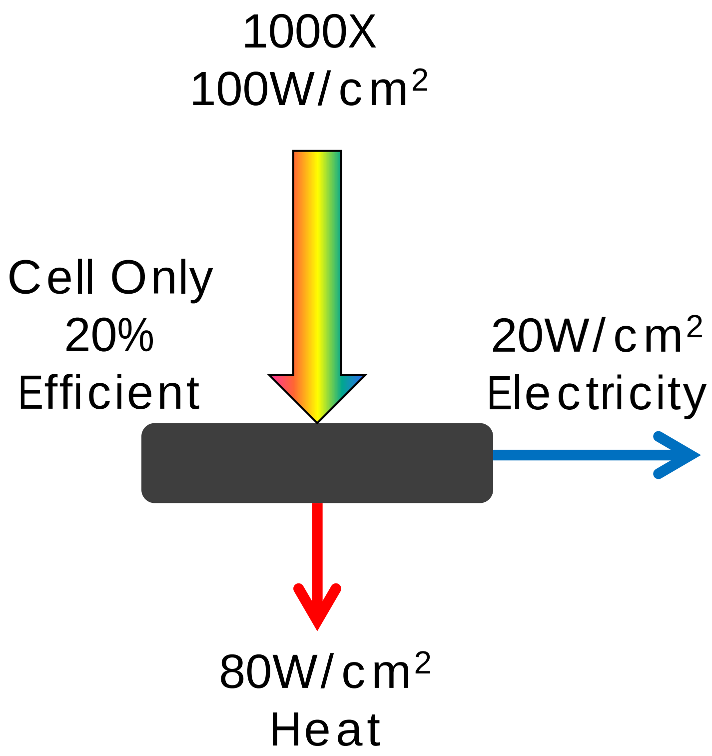
Multi-junction cells with band pass light filters



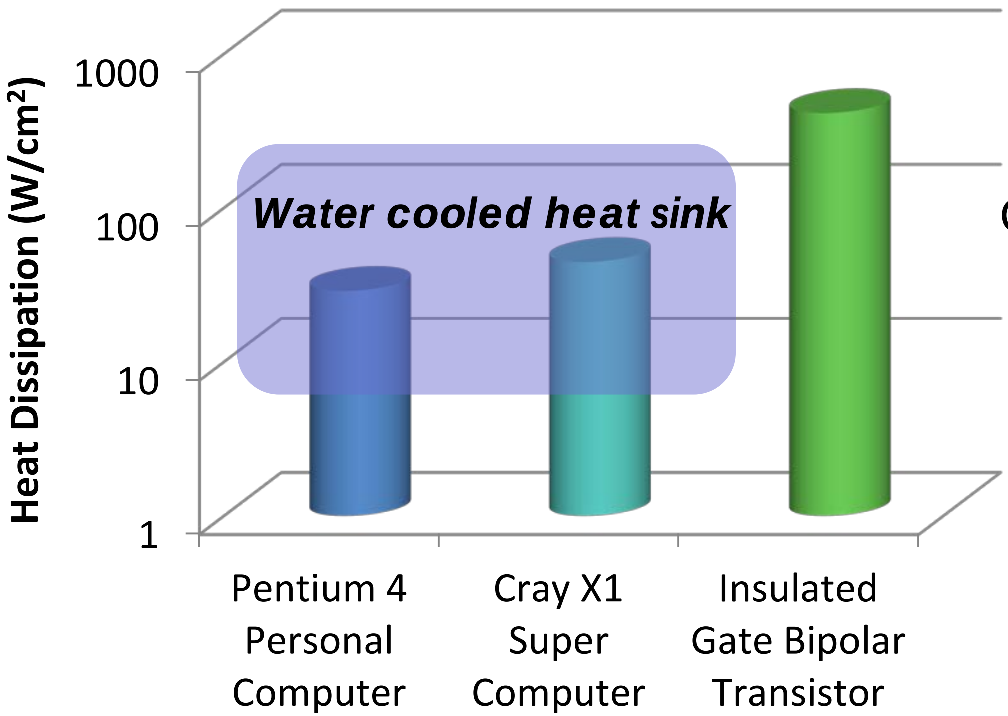
Goal: > 60% efficiency, < $1/Watt

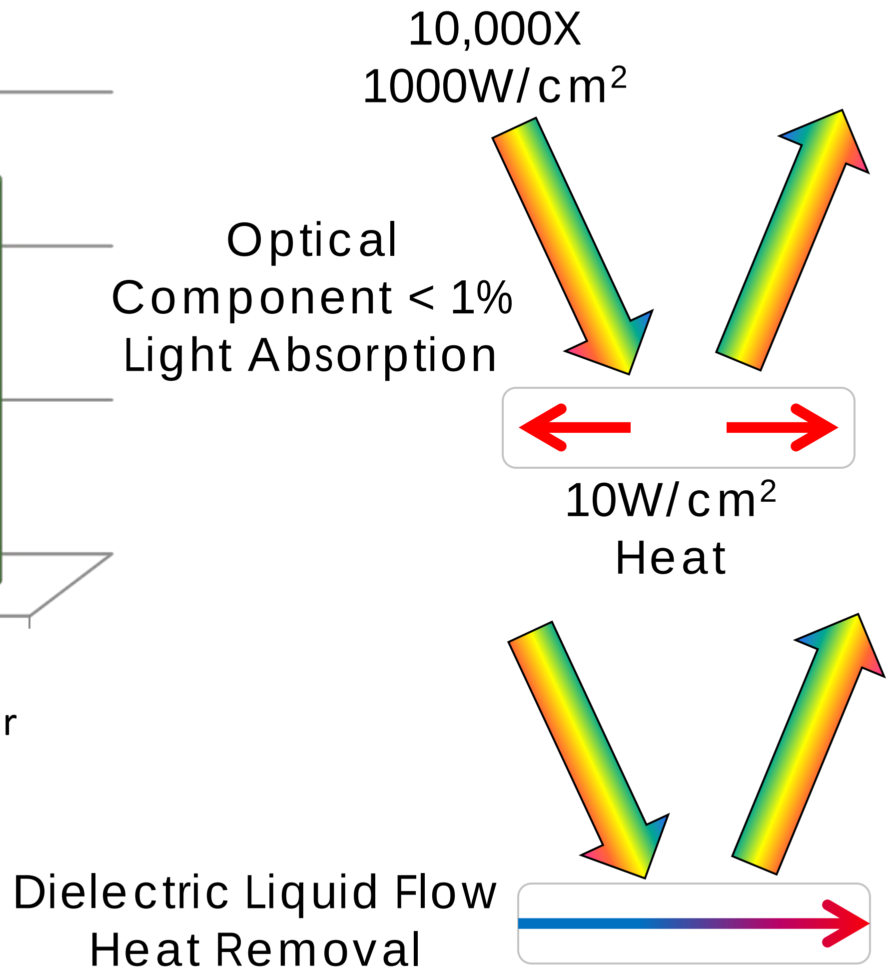
Can We Handle The Heat?





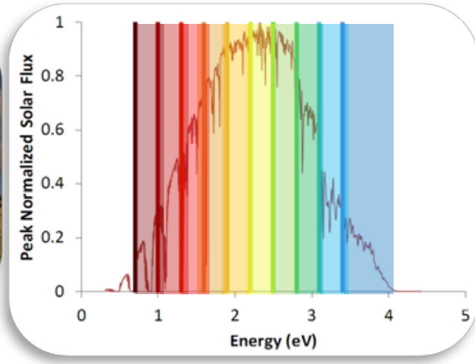
Can We Handle The Heat?



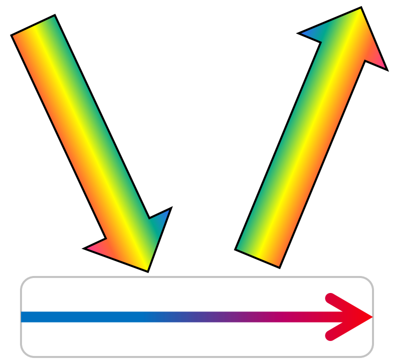


Collection

Spectral Splitting for Higher Efficiency



Optical Systems With Integrated Cooling



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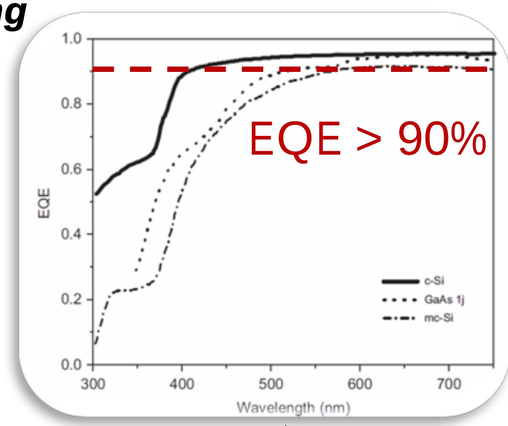

Optical System Improves Efficiency

Potential Program Name:

PHOTOVOLTAICS

HIGHLY

OPTIMIZED

THROUGH

OPTICAL

NETWORKS